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Pocket gophers occur only in North and Central America but within this vast area few other native rodent groups are more widely distributed (Anthony, 1928). None are more adaptable, either to natural extremes of habitat or to changed conditions brought about by agricultural development and other man-made environmental modifications. They occupy coastal areas, inland plains and valleys, desert and alpine meadow, from sea level to above timber line in a multitude of vegetation and soil types. This practically universal distribution has, of course, led to the recognition by naturalists of many species and subspecies. California alone contains at least 75 species and subspecies all within the one genus Thomomys — the western pocket gopher — which includes all species from the Rocky Mountains west (Grinnell, 1933). The eastern pocket gopher, genus Geomys occurs in the eastern Gulf States and all over west-and-north-central America. A third genus occurs in parts of southwestern United States and there are five other genera in Mexico and Central America (Scheffer, 1931).

This animal is so well known that detailed description is not necessary here* Although other rodents, and in the southeast a land tortoise, are locally known as "gophers", the true pocket gopher, whose name was derived from its external, fur-lined cheek pouches, or "pockets", is very uniform in general characteristics, behavior and food habits regardless of local variations of color, size and specific habitat adaptations.

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Gophers, like many other creatures of specialized existence are remarkably well equipped for it. Their outstanding physical characteristics are development of legs, feet and claws for digging to create shelter and obtain food, exceptional tooth development for harvesting of food, and those useful pockets for transporting it.

In contrast to most mammals, even their fellow burrowing rodents such as ground squirrels, prairie dogs and mice, gophers have adopted a life of almost full time underground seclusion. They do graze, so to speak, on the surface within a few inches -- usually a body-length or less — of feeding holes which they construct up from their main burrows. They also travel above ground in changing territory, but for the great part of their existence including food gathering and storage, mating and nesting, escape and protection from enemies they live within their individual network of specially-constructed underground tunnels.

I say individual network because gophers, unlike mice and ground squirrels and other gregarious rodents, are solitary animals. Except during the mating season, or during the time the young are still with the mother before they must emigrate to establish their own burrows, there is only one gopher per burrow system. This factor of solo underground existence is important in several respects. First, it definitely limits area abundance, A population density of 50 gophers per acre is quite high but meadow mice may reach 20 times this number during population irruptions. Diseases which can exert sudden and severe reduction in more crowded rodent populations are not as readily transmitted among gophers because of their isolationist attitude; therefore, gopher population trends are not as markedly cyclic as those of some other species.

To maintain their independence, gophers must defend their territory against invasion by their own kind. This they do, and they often fight to the death regardless of age or sex of the opponent.

This characteristic of underground solitude also makes control methods difficult and expensive.

Reflected in the reproductive potential of an animal species is its relative survival ability. Since gophers are comparatively secure in their burrows they are not prolific breeders by rodent standards. Many studies have shown litter sizes averaging about four (Cummings, 1942-1949, Hanson, 1960, Scheffer, 1931, Tryon, 1947). This is only about half that of rodents which face greater survival hazards.

In most latitudes and average conditions of habitat gophers produce but one litter per year (Cummings, 1943-1947, Hansen, 1960, Scheffer, 1931, Tryon, 1947). However, it has been found that in warm climates with favorable year-round food conditions such as those offered by irrigated crops a second, or even a third litter may be produced (Miller, 1946, Scheffer, 1931).

The breeding season is an extended one so that all age classes may be represented at almost any time of year, but in general it is confined to the warm months.

The great volume of soil moved by gophers in constructing their tunnels results, of course, in the familiar surface mounds. All gophers do not bring soil to the surface at the same time nor is this a constant activity. As the soil becomes hotter and drier gophers tend to move deeper and may pack earth from new, deep excavations into upper, now inactive burrows* There also may be extended periods during wet or cold weather in which surface activity stops, but gophers do not hibernate. Because of the erratic

pattern of formation of surface mounds their number, size and frequency of appearance are not at all times reliable indicators of gopher abundance.

The mounds themselves are a detriment in many situations. They are disfiguring in lawns, gardens, cemeteries, golf courses and parks and are damaging to agricultural equipment such as mowing machines and silage harvesters. They also cover forage plants and serve as seed beds for less desirable species (Turner et al., *1959).*

Gopher burrows are a factor in accelerated erosion of mountain soils (Ellison, 1946) and are an aggravating and expensive nuisance to users of irrigation water by causing breaks in irrigation checks and ditch banks. Much water can be wasted down the barrows themselves.

The chief damage caused by gophers is their cutting of roots and stems, either for food or merely because these are in the way as burrows are dug. They sometimes cut off roots, then pull the entire plant beneath the surface where they can chew off lengths to be transported in their cheek pouches to underground storage chambers. Root girdling, especially on young stock, causes loss of orchard and ornamental trees which is particularly costly. Production of alfalfa and other field crops can be seriously reduced not only by gopher foraging but by actual destruction of plants; this often shortens the profitable productive life of perennial stands.

There are few plants which gophers will not eat but they do exhibit preferences. Fleshy-stemmed or bulbous-rooted plants are relished more than fibrous species such as many grasses. Legumes are high on the gopher's preferred foods list and for this reason alfalfa fields and pastures or lawns containing clover may attract and support high populations of gophers.

The idea that gophers can be discouraged or driven off by the presence of plants which they dislike is a popular one. While it is true that fewer gophers will live on an area covered by plant species they do not prefer there are not truly "gopher repellent" plants which will cause them to leave. The castor bean is commonly said to have this property but there is no foundation for the belief. Chemical repellents, useful against some pest animals, are of no established value for gophers.

The nearest control measure to this is the removal of gophers by use of herbicides, but actually there is no correlation between the two. It has been found that weed control with herbicidal sprays resulted in removal of up to 90% of the gopher population (Cummings, 1946-1948, Keith, et al., 1959). This was on large acreages of range lands where weedy plants, forbs preferred by gophers, were the dominant vegetation. The Forest Service has used this procedure to accomplish both weed and gopher control in range improvement programs. The gophers are killed not by direct chemical effect but by removal of their food supply (Hansen, et al., 1958). The herbicide treatment is then followed by seeding of range grass species which offer much less food for gophers but more forage for livestock. This is simply ecological control obtained by altering the habitat from favorable to un-favorable so far as gophers are concerned.

Fumigation, a successful method for controlling some rodents, is of limited effectiveness. Gopher burrow systems are extensive and portions of them are blocked off by earth plugs as the gopher occupies various portions at a time. It is difficult to maintain lethal concentrations of gas, particularly if the soil is not moist and tight, and unless the gas is applied under pressure. For this reason materials such as solid calcium cyanide which generate gas rather slowly are not usually effective. The common method of using a flexible hose to pipe automobile or tractor exhaust fumes into the burrow is perhaps most effective because it forces gas

through all open burrows almost instantly. Gassing is an expensive method of control and ordinarily is not recommended.

Flooding may be used to drive gophers from their runways but few actually drown. Individual gophers in lawns and gardens can be forced out by turning the stream from a hose down the burrow so the gopher can be clubbed as he emerges. During flood irrigation of fields the gophers move to the levees and field borders and while tending the water the irrigator can account for many with his shovel, if he has time, and some dogs learn to patrol the levees to kill gophers while the water is on the field. Sprinkler irrigation has no effect on gopher abundance because the water percolates around, not into, the gopher tunnels as it penetrates the soil. Some of our maximum gopher populations are on sprinkler-irrigated alfalfa fields.

In home situations where small gardens or ornamental plantings of high value need protection from gophers this can be accomplished by fencing. To protect against both underground and overland invasion the fence of small-mesh wire, sheet metal or concrete should extend a foot above ground and two feet below. Individual plantings such as young trees can be given protection by enclosing them in a wire mesh basket or cylinder. This should also be of two foot depth but need only come up to the surface of the ground. In cases of unusually heavy and persistent burrowing in canal and ditch banks the underground fence of wire mesh or concrete can be used also. This is an expensive procedure and would be warranted only if gopher damage was quite costly.

Reductional control of pocket gophers is best accomplished by trapping and poisoning. As previously stated, gopher control is difficult and expensive. This is because the bait or trap cannot simply be placed on top of the ground near a gopher mound but must be carefully located in the underground burrows. To locate these the

operator must use a probe and is guided by the presence of the mounds. Probing is done not in but near the mound until the tunnel is located. Most mounds are slightly fan-shaped or horseshoe shaped and the burrow will come up from the smaller or lower side. As the probe penetrates the roof of the tunnel it will suddenly drop or at least slide easily indicating the open burrow has been reached. This is slow, tedious work and is subject to lots of error even when the operator is experienced and conscientious.

Many special gophers traps have been devised but two kinds, a choker type and a double-pronged snap type, are most widely used and give best results. Traps are the best method for home situations and for follow-up work to take individual gophers. They are quick and positive when properly set and give satisfaction in knowing that a particular pest has been accounted for. The Macabee trap has been a standard gopher control item for many years. It is inexpensive to buy, lasts indefinitely and is simple to use; it is undoubtedly the most widely used trap in this and many other states. A box-type choker trap, the California gopher trap, is next most frequently used here. The box trap is most commonly used in southern California, being a particular standby in many citrus orchards where gophers are a problem of greatest economic importance. Traps should be set in an open, main-traveled burrow, not in the lateral tunnels which lead to surface mounds or feeding holes. It is best to set two traps, one facing each direction in the tunnel. Traps should be firmly placed, well into the tunnel with as little disturbance as possible. The opening made in order to set the trap should then be covered with sod or clods so that little light reaches the trap. Gophers keep their runway systems closed as protection against their enemies such as snakes and weasels, so if too much light is showing as the gopher approaches the trap he will

gather a load of dirt and push it ahead of himself to use in closing the break. This will, of course, spring the trap or plug it up. Traps should be fastened in place with a light wire and stake.

Over large areas heavily infested with gophers the fastest and cheapest control method is by the use of poison baits. To do this by hand the probe method is used to locate an open burrow. Poison bait is then dropped through the probe hole after this has been enlarged by reversing the probe and forcing the handle into it. A trowel or large spoon is sometimes suggested for use by the home gardener but care should be taken not to drop dirt into the tunnel or to cover the bait with dirt.

Several dispenser-type probes have been constructed. These have a hopper at the top of the probe which holds poison grain. When the runway is located by the probe point a trigger is pressed which releases a charge of bait into the burrow without the probe having to be withdrawn, the hole then enlarged and the bait spooned into the hole. This one-operation method will speed hand baiting very considerably.

Baits used in gopher control may be either grain or vegetables coated with poison. For home use on a few gophers the cut vegetable bait is easiest to prepare and is readily accepted. The carrot, sweet potato or other root vegetable should be cut into half-inch cubes or pieces not over two inches long. The vegetable should be peeled and the tip end discarded to avoid infesting the soil with nematodes which the carrot or sweet potato may have. Baits should be placed in at least two locations in the runway system after they have been dusted with strychnine alkaloid, (One-third ounce of strychnine will treat *h* quarts of cut baits,) Obviously this is a slow process not suited to large-scale work.

Poison grains are used for treating large areas. Strychnine is the most commonly used poison and barley, wheat, oats, maise and other grains are generally prepared at the rate of about *1/4* to 1/3 of one per cent strychnine (5 oz./lOO lbs.= 0.3%). Such baits can be purchased ready-mixed from pest control supply firms and in California from County Agricultural Commissioners. The Bureau of Sport Fisheries and Wildlife sells baits to official cooperators.

Other poisons are sometimes used, the most effective for some conditions being Compound 1080. This chemical and baits prepared with it are not available to the public for individual use. It can be used only by and under direct supervision of licensed professional operators and governmental agencies. In California all use of Compound 1080 for control of field rodents is under the jurisdiction of the County Agricultural Commissioner.

A new approach to gopher control has been recently made possible through the use of a mechanical method of applying poison baits. (Kepner, et al, 1961, Ward & Hansen, 1960). This tractor-drawn device constructs an artificial burrow and meters poison grain into it. The operator drives the machine across a field at regular intervals, ordinarily about 2O-25 feet, with the burrow-forming point at a depth of 8-10 inches which intercepts the natural burrows. The gopher's curiosity and that territorial aggressiveness which prompts him to claim a burrow as solely his property lead him to investigate this new tunnel and find the bait.

No dependence upon surface mounds or gopher activity, no probing and hand placement, no particular skill on the part of the operator is required. He merely drives back and forth across a field treating 5 to 10 acres per hour. Many tests on thousands of acres have established that with proper bait and soil conditions one application

should result in a kill of 80% or more. It is essential that a fairly open burrow be constructed which means that soil moisture should be high. On agricultural lands moisture should be at the upper limit for plowing. In the case of irrigated fields this treatment can be fitted into the irrigation schedule; a few trials will determine how soon after irrigating will the best burrow be formed, which, of course, differs in various soils. Treatment may be made at any time of year whenever work schedules and soil conditions are favorable.

In controlling the Thomomys gophers in California it has been found that the low-percentage strychnine baits as used in hand-baiting gophers or for control of ground squirrels do not give satisfactory results. Grain treated with 2 oz. of 1080 per hundred pounds (used only under supervision of County Agricultural Commissioners or other authority as required by law) or with much higher strychnine content are necessary to achieve the 80% or better figure quoted previously as typical of the method. In contrast to hand baiting where a lethal amount of strychnine or other poison is found in one place by the gopher, the animal encounters only a few grains at a time where mechanically placed. This means that with a fast-acting poison such as strychnine the gopher may feel distress symptoms before he has ingested a lethal amount. Much research and testing to find a strychnine level which would match the effectiveness of 1080, the most effective but un-available material for public use, resulted in the adoption of a 3.0% strychnine formula to be used in this mechanical method. Hulled grains, wheat, oats, or barley are recommended for this purpose and the standard formula being mixed and sold in many California counties calls for 100 pounds of plump wheat (White

Federation is a favorite), and 48 ounces of strychnine.

Strychnine is expensive and this formula brings the cost of bait to $1 or more per pound, or five or six times the price of 1080 bait. Present instructions call for only one pound per acre by mechanical baiting, however, so because of the tremendous increase in time-saving and effectiveness it is still economically justifiable in protecting pastures, alfalfa and other forage, orchards and many other crops. In other areas, less expensive baits can be used where different gopher species are involved, or where work with 1080 bait can be supervised.

There are now hundreds of these machines in use in many parts of the United States. This method is the first to promise effective, economical control of pocket gophers on large acreages of agricultural lands, (Slides of Mechanical Gopher-Bait Applicator).

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